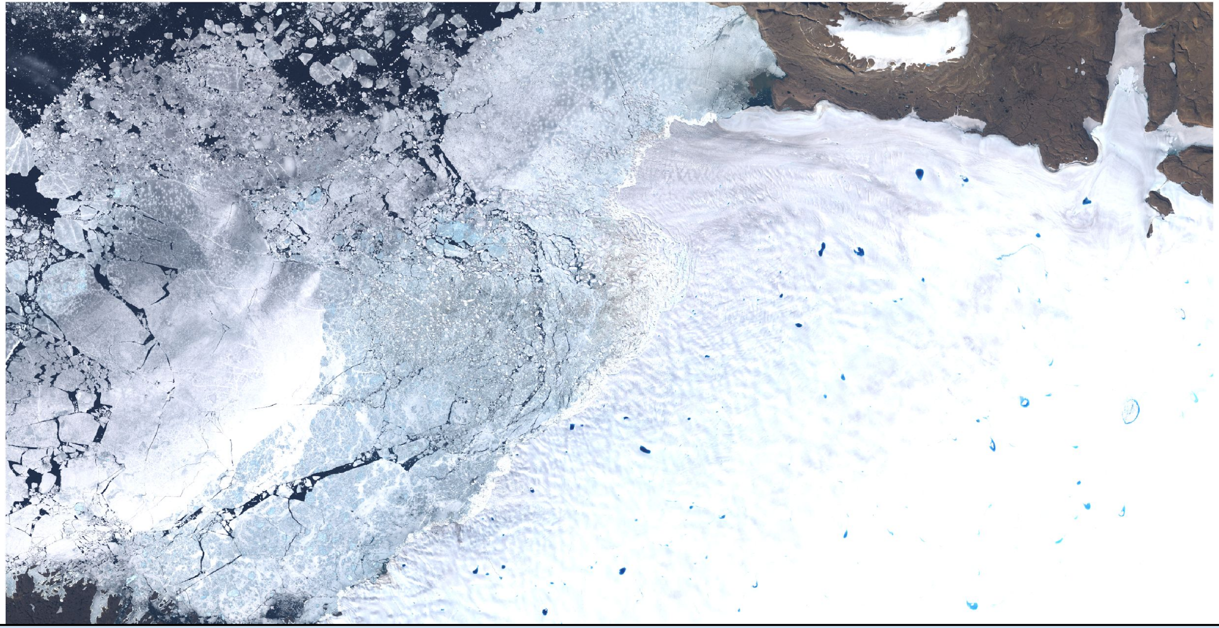
Retreat of Humboldt Glacier, north Greenland

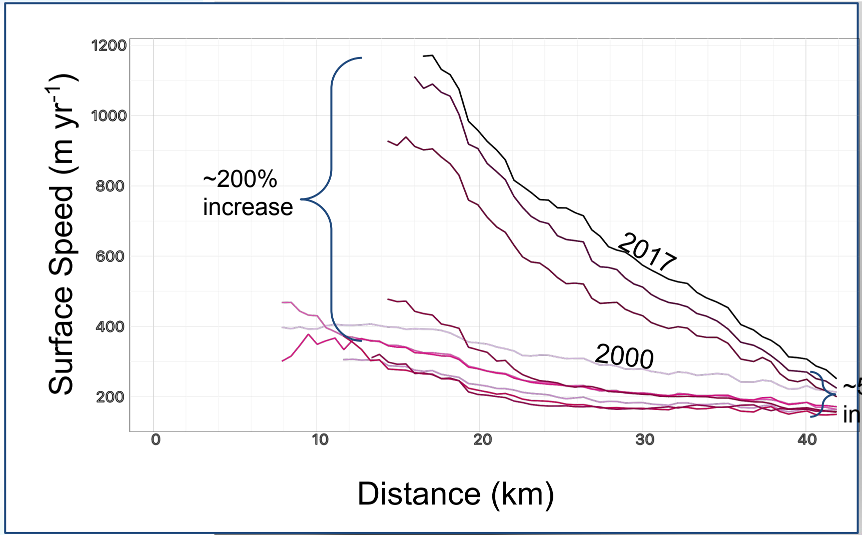


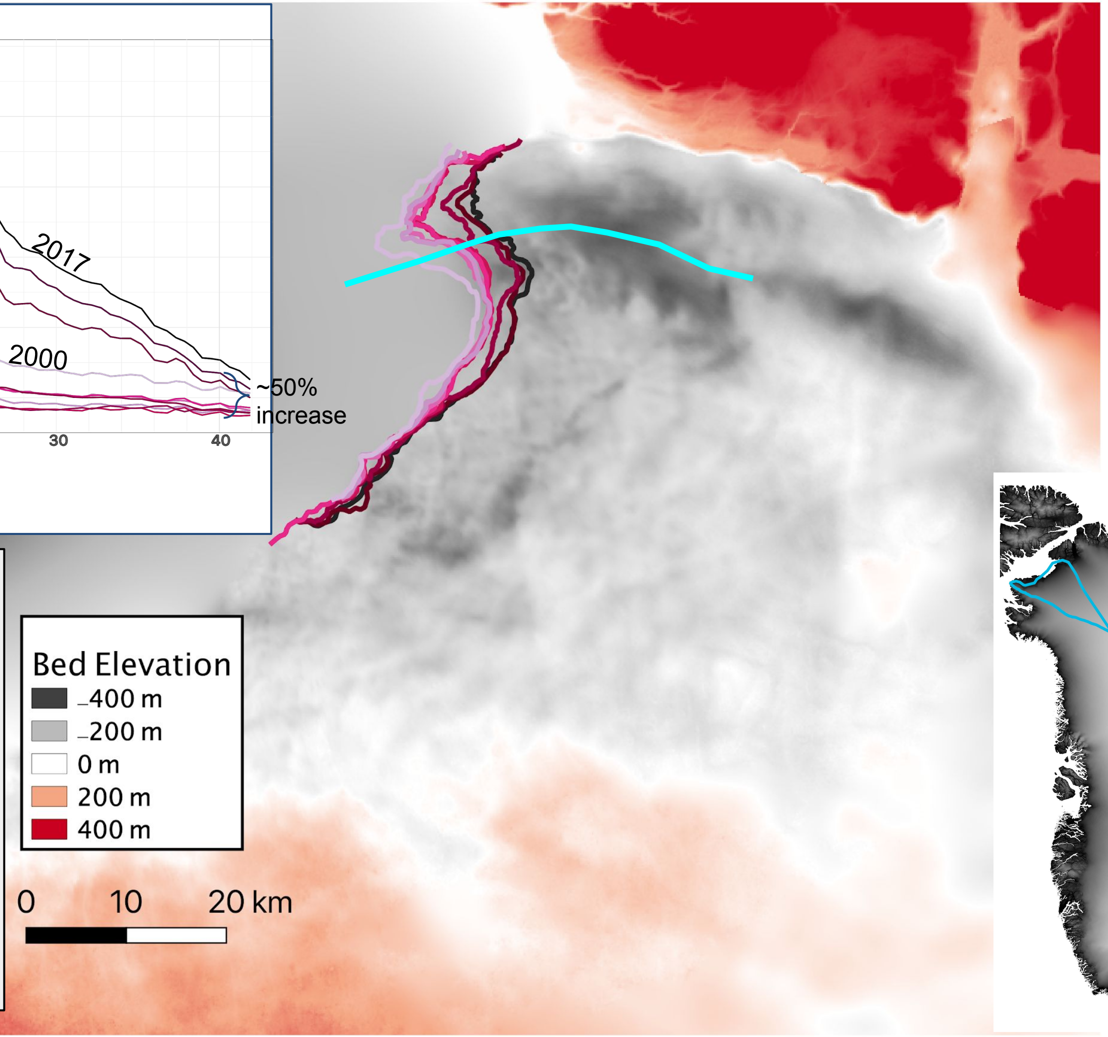
Trevor Hillebrand[1], Matthew Hoffman[1], Stephen Price[1], Mauro Perego[2], Abby Roat[3], Ian Howat[4]

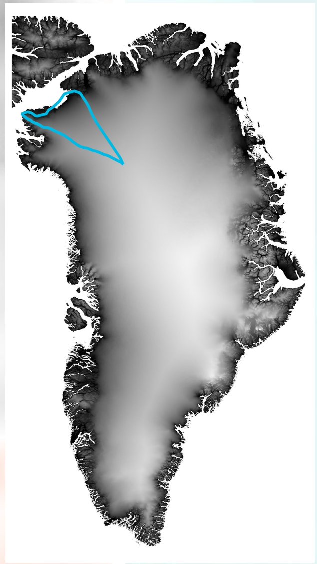
(1) Los Alamos National Laboratory, (2) Sandia National Laboratories, (3) Colorado College, (4) The Ohio State University

Energy Exascale Earth System Model

U.S. DEPARTMENT OF ENERGY







Questions:

A) Is ocean forcing, surface melting, or bed topography controlling Humboldt Glacier retreat?

B) Has Humboldt reached a phase of unstable retreat?

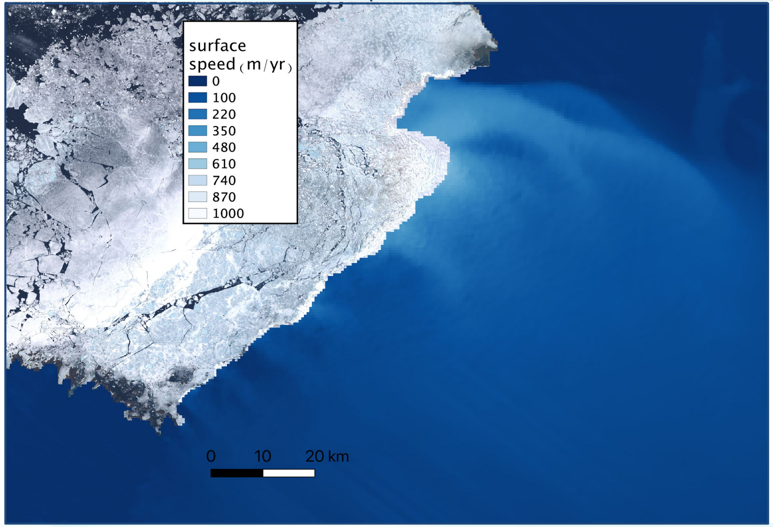
C) How much and how fast will Humboldt Glacier contribute to sea level in the 21st century?

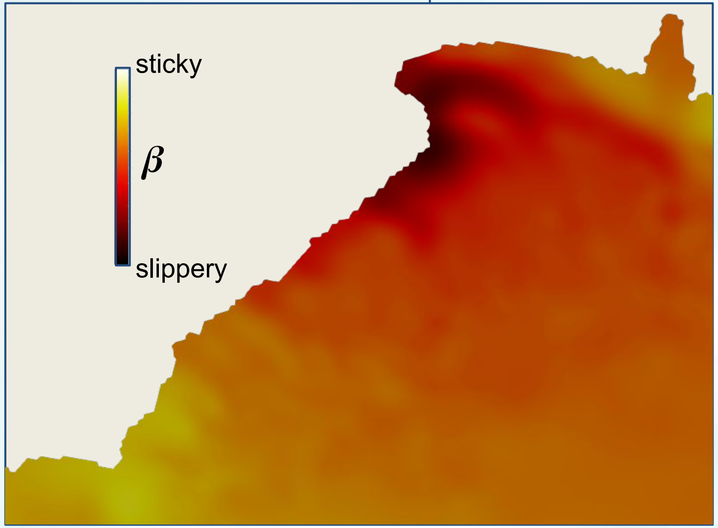
Basal traction optimization

find β to minimize:

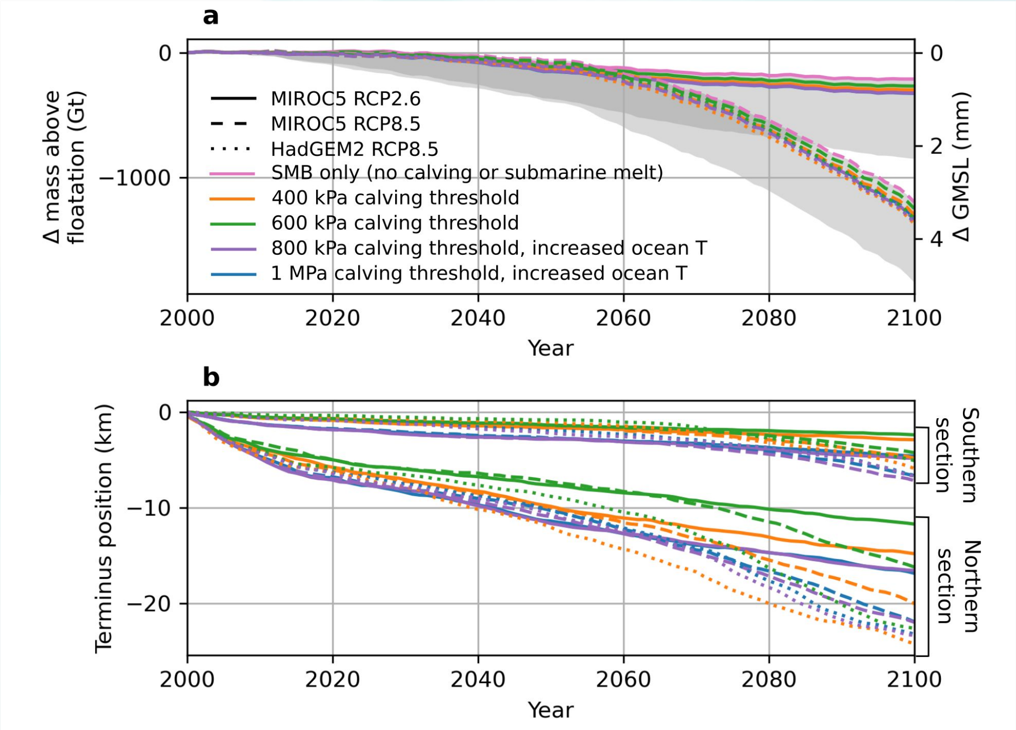
velocity mismatch regularization

$$\mathcal{J}(\beta) = \int_\Omega \frac{1}{\sigma^2} |u - u^{obs}|^2 ds + \mathcal{R}(\beta)$$



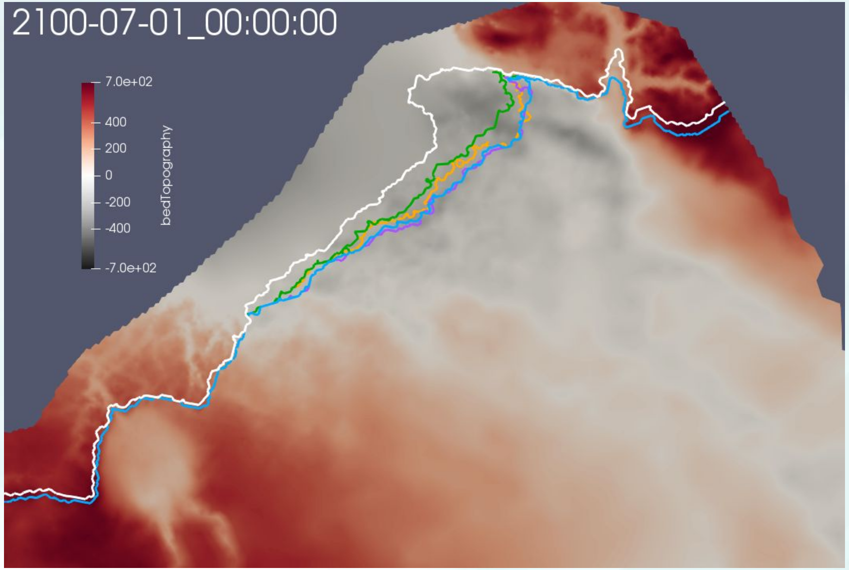


Projections to 2100

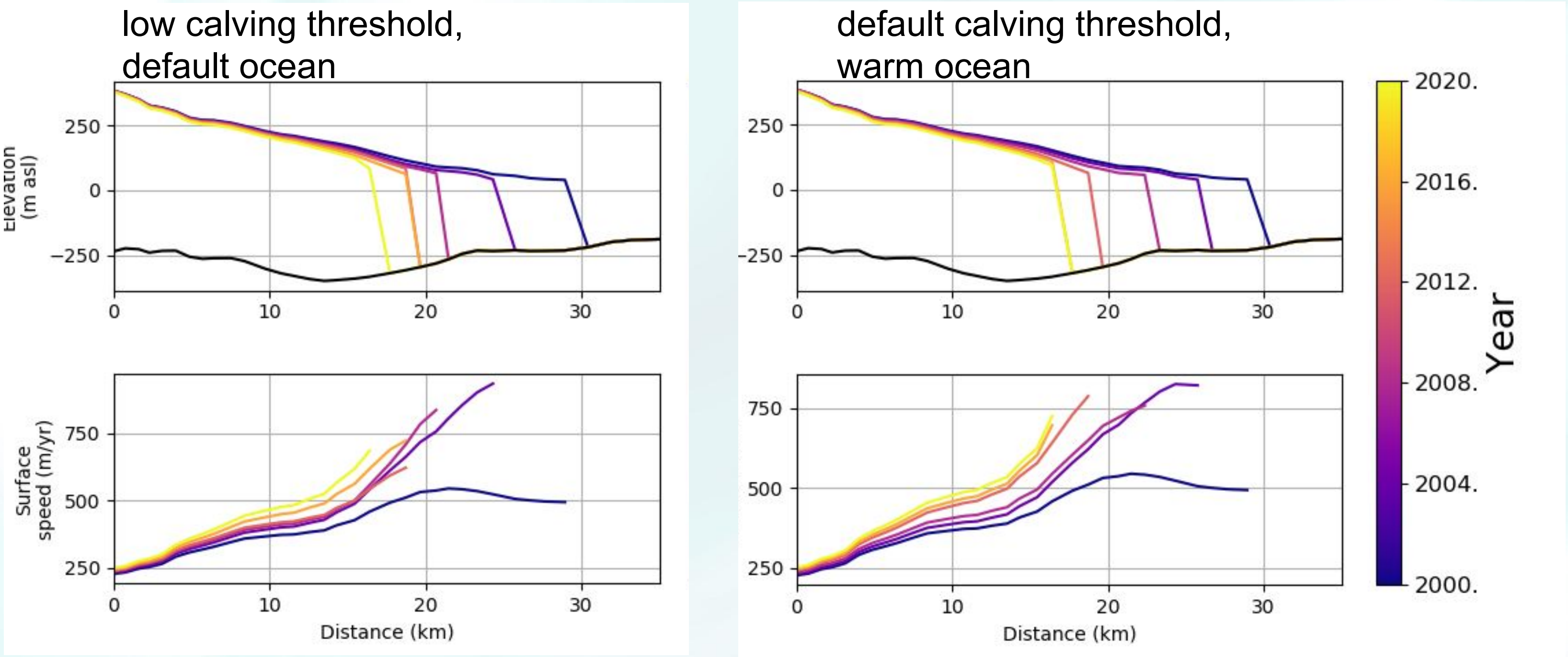


1) Using MALI, tune model to observed terminus retreat rates
(250–350 m/yr in north, <100 m/yr in south)
   a) Calving stress thresholds: 400–1000 kPa
   b) Ocean temperature increase: 0–3K
   c) One constant melt-rate: 2 m/day

2) Run best-fitting parameter sets out to 2100 with RCP2.6 & RCP8.5 forcing



Two end-member simulations that fit observed terminus retreat:



Ensemble experiments reasonably reproduce observed glacier-front retreat, but they do not reproduce the observed three-fold increase in surface speeds. So, 3.5 mm is likely a lower bound on sea-level rise from Humboldt by 2100. Possible explanations:

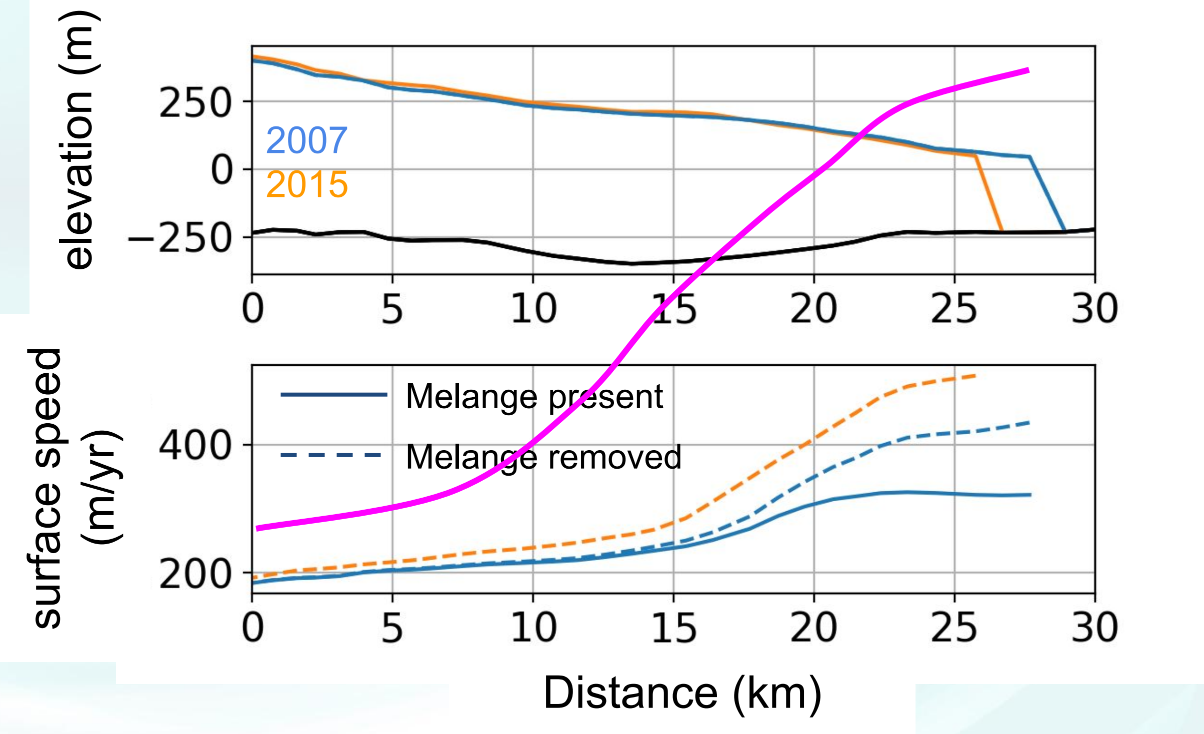
1) Change in melange buttressing; 2) Change in basal lubrication; 3) Non-linear bed rheology

Melange buttressing

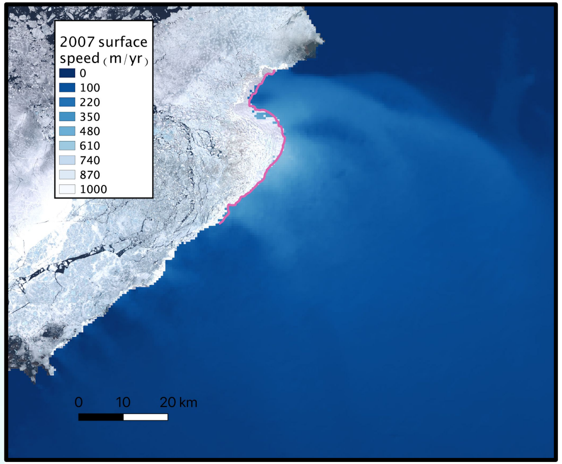
1) Repeat 2007 basal traction optimization with strong buttressing provided by melange. $6x10^7$ N m^{-1}: largest value found in literature (≥2x most estimates)

2) Instantaneously remove melange force and compare velocity solutions

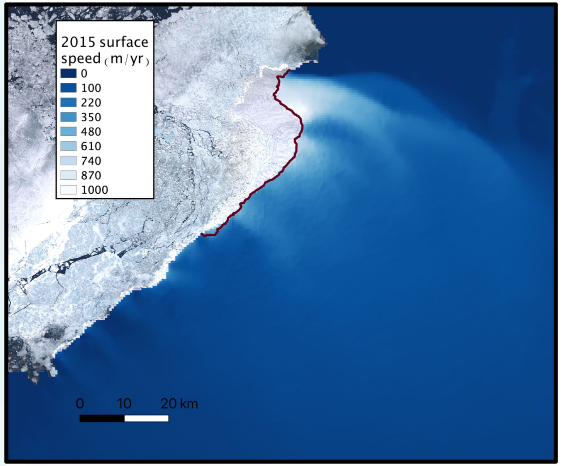
Melange removal by itself does not explain magnitude or pattern of speed-up. We are looking for something more like the pink curve:



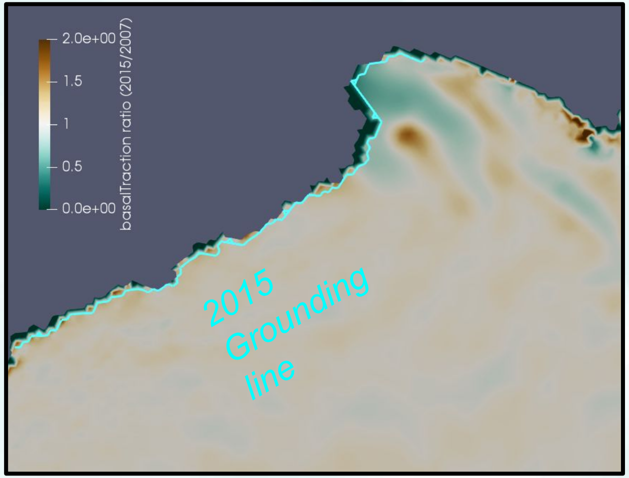
Optimizations suggests a ~50% decrease in basal traction from 2007 to 2015, but this could suggest either increased water at the bed or a non-linear bed rheology.



2007 velocity data



2015 velocity data



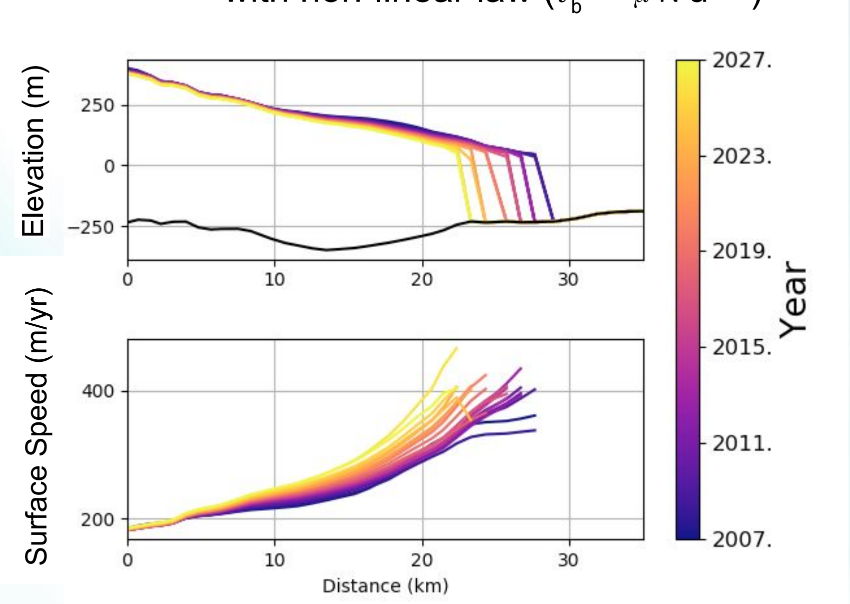
Optimization results

Preliminary experiments with non-linear bed rheology are promising

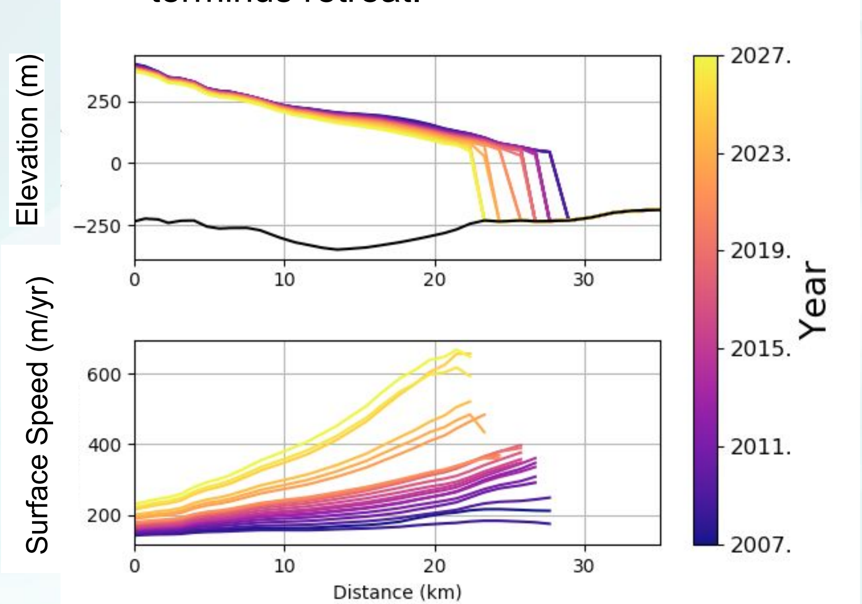
1. Tune hydrology model so that water pressure ≥ 90% ice overburden pressure

2. Calculate $\mu = \tau_b / N$
   where N = ice pressure - water pressure
   $\tau_b = \beta$ x basalSpeed

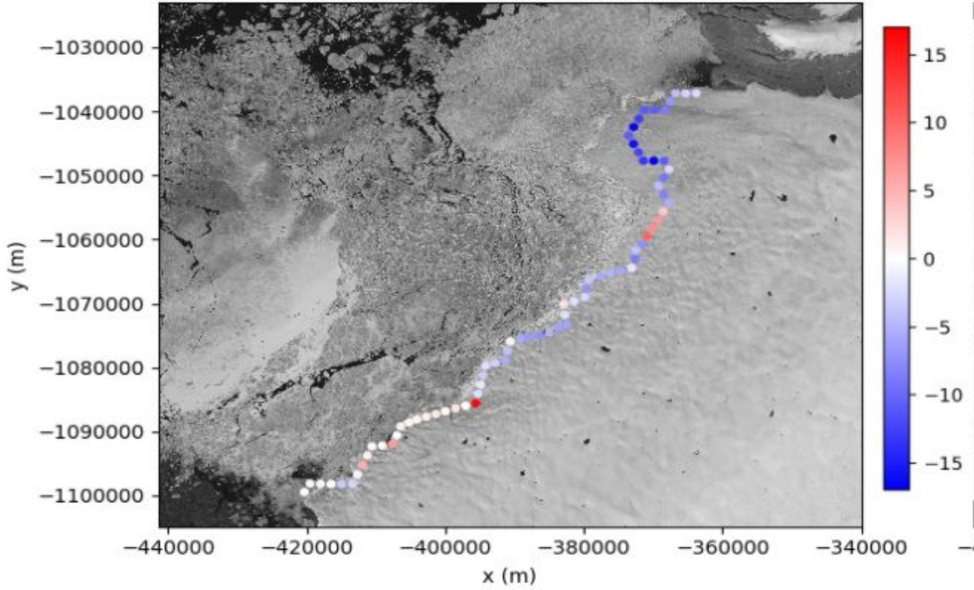
3. Replace linear law ($\tau_b \propto \beta u$) with non-linear law ($\tau_b \propto \mu N u^{1/m}$)

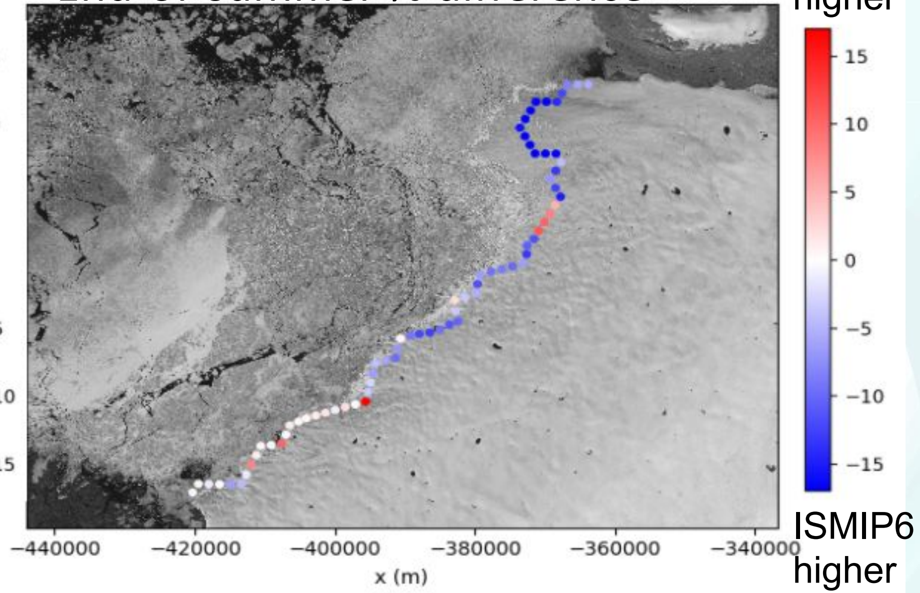


4. Repeat forward runs to match terminus retreat.



Subglacial hydrology effect on melt rates





ISMIP6 melt-rates 5±6% higher than MALI

ISMIP6 melt rates 8±8% higher than MALI

Summary

1) New calving and melting routines in MALI for grounded marine glacier termini
2) Preliminary ensemble experiments predict ~3.5 mm SLR from Humboldt Glacier by 2100 with RCP8.5 forcing
    a) ISMIP6 multi-model ensemble predicts total GIS contribution of 100 ± 35 mm.
3) However, these experiments do no accurately reproduce acceleration during retreat, and thus 3.5 mm is **likely a lower bound** on sea-level contribution.
4) Loss of melange buttressing at the terminus cannot by itself explain the observed speedup.
    a) It could be one of several factors.
5) Preliminary experiments point to a non-linear bed rheology.
6) Subglacial hydrology model has a moderate effect on melt-rates at the glacier front when compared with uniform discharge. How important could this be for projections of glacier retreat?